Lighting Technology

Basic parameters used in lighting

Luminous flux – Luminous intensity – Illuminance – Luminance

- **Luminous flux**

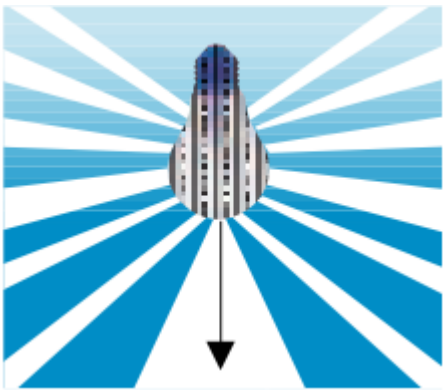
Luminous flux **(ϕ)** is the light emitted by a source and is measured in **lumens**

Symbol	ϕ
Unit :	Lumen

- **Luminous intensity**

Luminous intensity is the power of light from the source measured in **candela**

Symbol	I
Unit :	Candela (cd)



- **Illuminance**

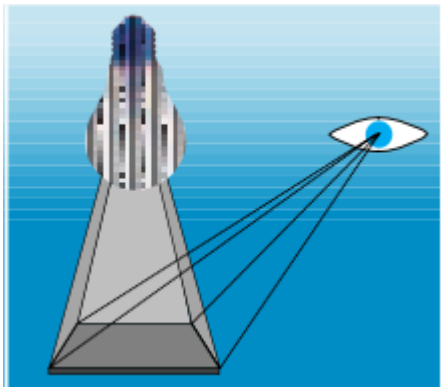
  Illuminance is a measure of the density of luminous flux at a surface measured in **lux** (lumens per square metre)

$$E\ (lx) = \frac{luminous\ flux\ (lm)}{area\ (m^2)}$$

- **Luminance**

Luminance is a measure of the light reflected from a surface measured in **candela per m^2**

Symbol	L
Unit :	cd/m^2



The luminous **efficiency:**

- is the ratio of the luminous flux to the electrical power consumed (lm/W). It is a measure of a lamp's economic efficiency.

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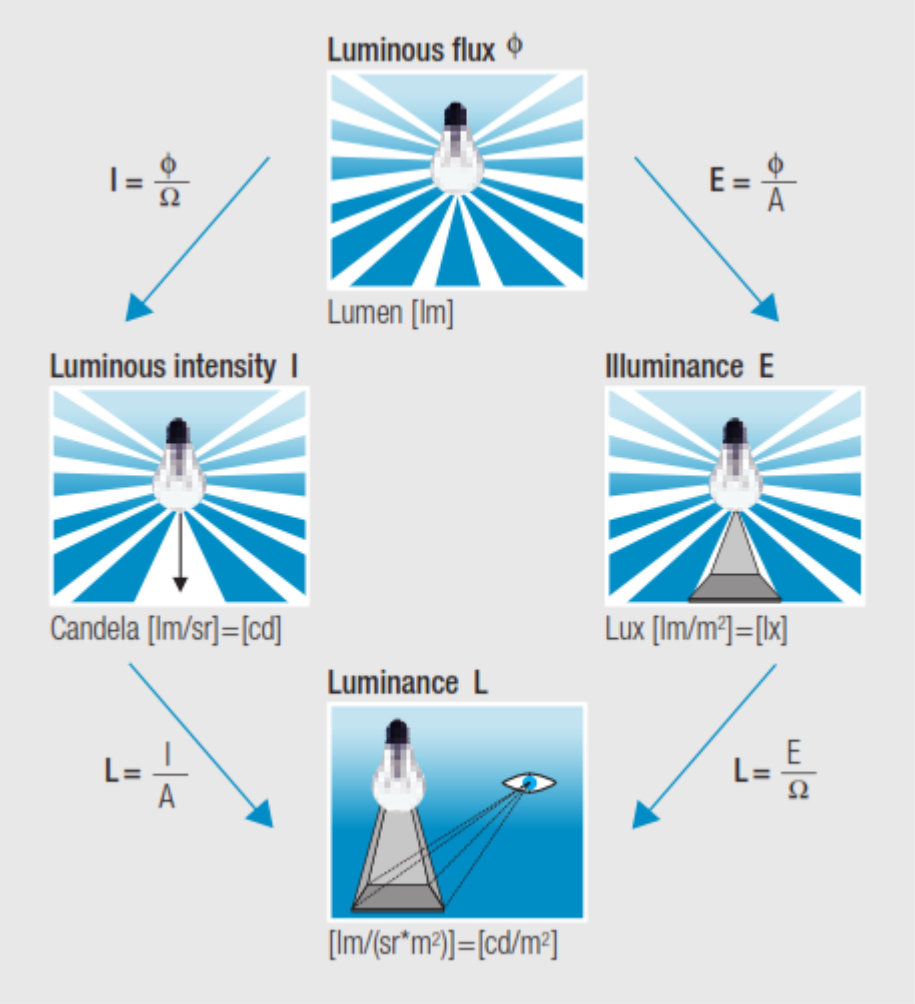
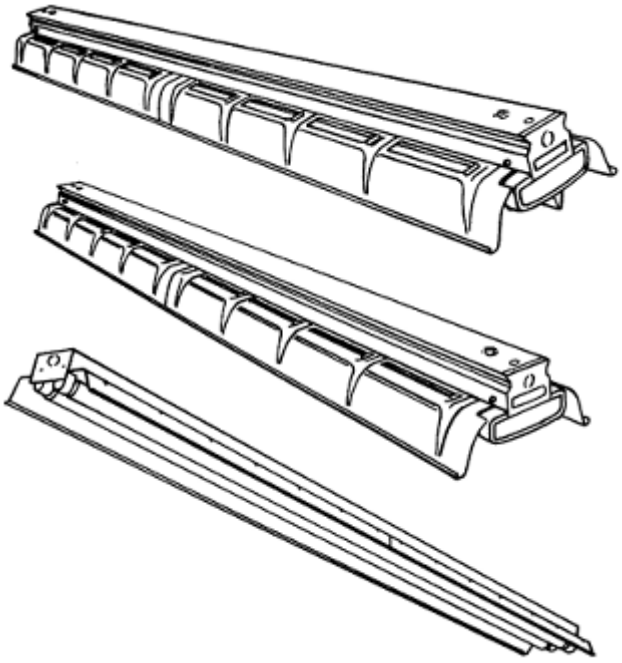
- Luminous **efficacy** is the ratio of the luminous flux emitted by a lamp to the power the lamp consumes this is measured in **lumens per watt.**



Luminaire

A **light fixture** (US English), **light fitting** (UK English), or **luminaire** is a complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply.

All luminaires have a fixture body and a light socket to hold the lamp and allow for its replacement. Also they may a have a switch to control the light. Typical luminairs are shown in Fig.1.



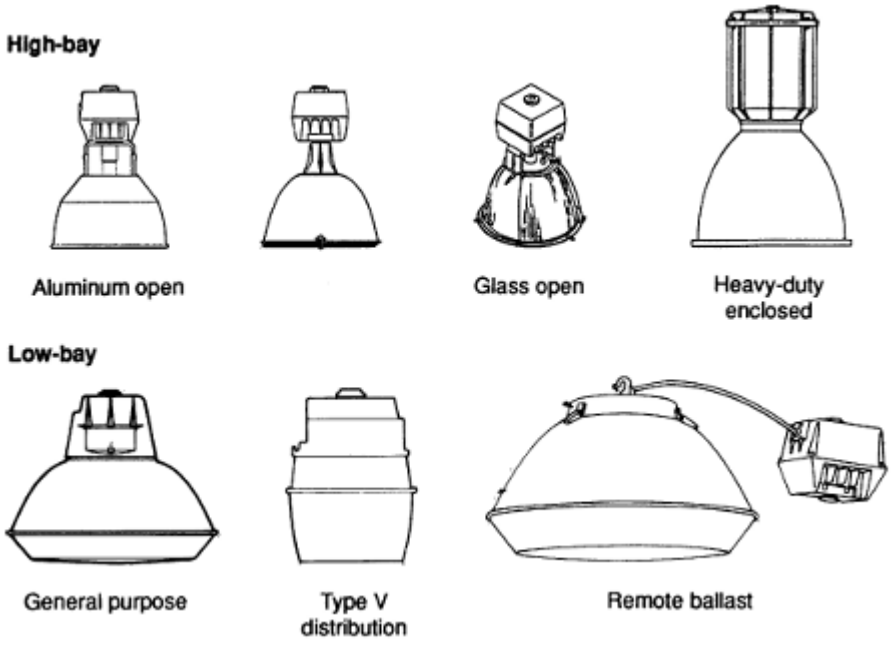

High-bay
Aluminum open
Glass open
Heavy-duty enclosed
Low-bay
General purpose
Type V distribution
Remote ballast

Fig.1

Lighting calculations

UNITS AND QUANTITIES

Quantity	*Quantity symbol*	*Unit*	*Unit Symbol*
Luminous intensity	I	Candela	cd
Luminous flux	Φ	Lumens	lm
Illuminance	E	Lux	lx
Luminance	L	Candela square metre	cd/m^2
Luminous efficacy		Lumens per watt	lm/W

Methods of Lighting Calculation

In general , there are three methods of lighting calculations :

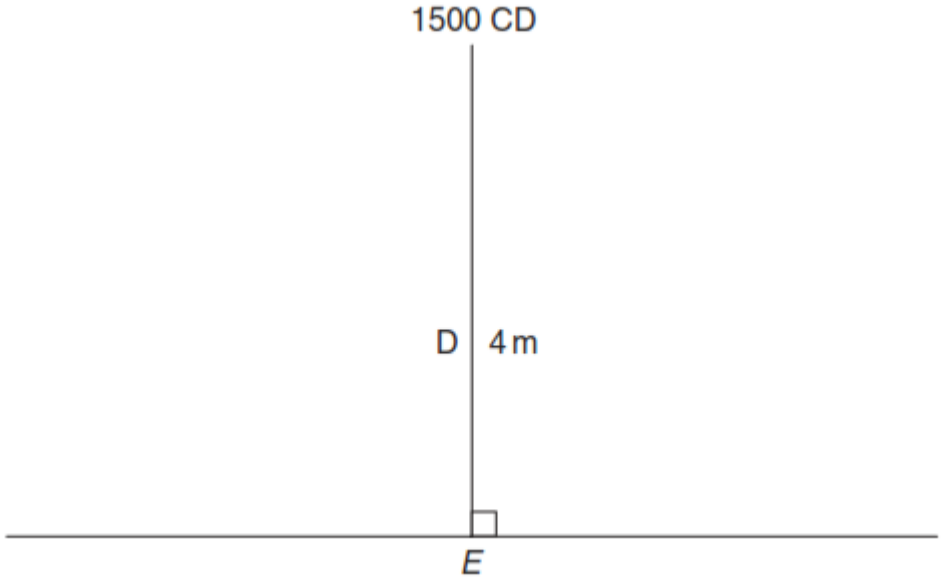
- Inverse square law
- Cosine law
- Lumen method (most common)

Inverse square law

When using the inverse square law, the distance used in the measurement is from the light source to a point directly below it. When a lamp is suspended above a surface, the illuminance at a point below the lamp can be calculated:

$$\text{Illuminance } E = \frac{(I)\ \text{candela}}{\text{distance}^2}\ \text{lux}$$
$$= \frac{I}{\text{d}^2}$$

EXAMPLE 1 A luminaire producing a luminous intensity of 1500 candela in all directions below the horizontal, is suspended 4m above a surface. Calculate the illuminance produced on the surface immediately below the luminaire.



$$E = \frac{I}{\text{d}^2}$$
$$= \frac{1500}{4^2}$$
$$= 93.75\ \text{lux}$$

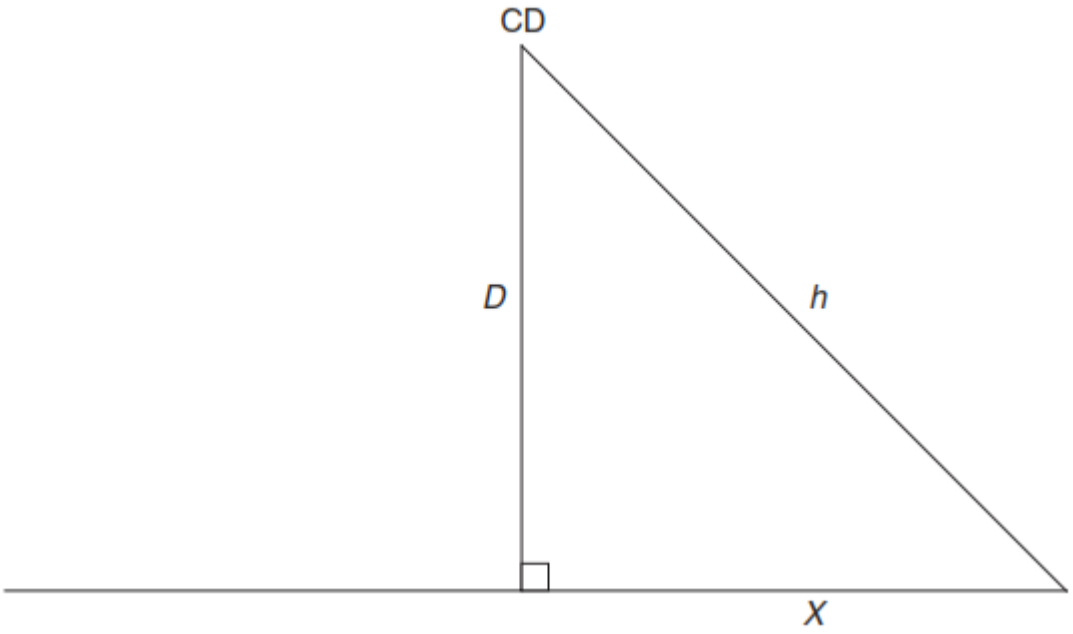
EXAMPLE 2 If the luminaire in Example 1 is raised by 1m, what would the new illuminance be at the point immediately below the surface?

$$E = \frac{1500}{(4+1)^2}$$
$$= \frac{1500}{5^2}$$
$$= 60 \text{ lux}$$

COSINE LAW

When using the cosine law, the distance used is from the light source measured at an angle to the point at which the lux value is required. When a lamp is suspended above a horizontal surface, the illuminance (*E*) at any point below the surface can be calculated.

$$E = \frac{I}{h^2} \cos\phi$$



To calculate h^2 (distance from lamp)

$$h^2 = d^2 + x^2$$

To calculate $\cos\phi$

$$\cos\phi = \frac{d}{h}$$

EXAMPLE 1 A light source producing 1500 candela is suspended 2.2 m above a horizontal surface. Calculate the illumination produced on the surface 2.5 m away (at *Q*).

Solution

Calculate h^2 using Pythagoras.

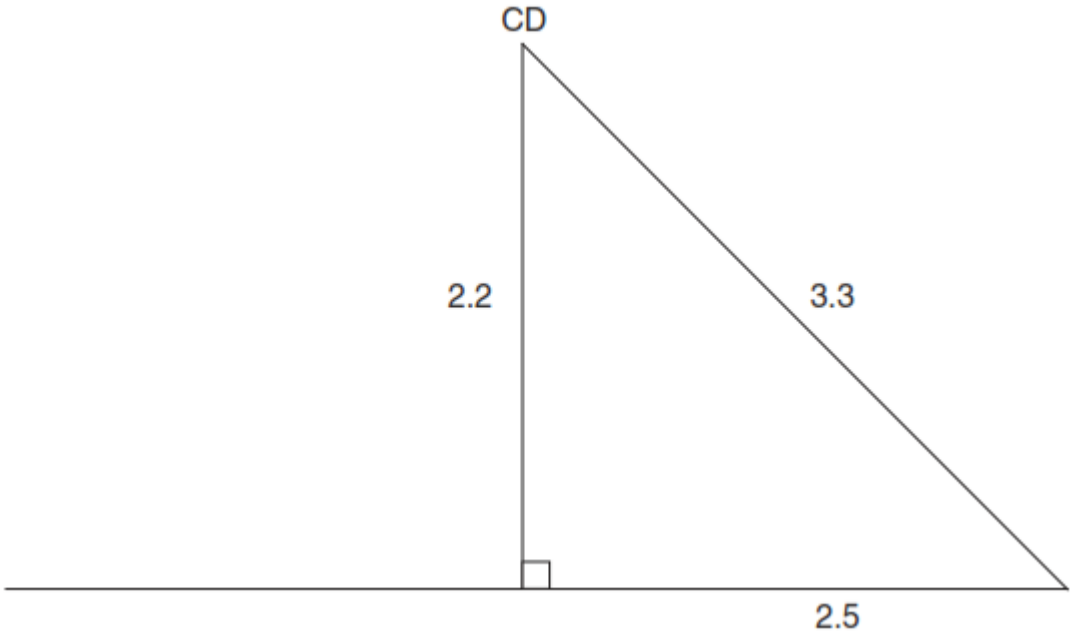
$$h^2 = d^2 + x^2$$
$$= 2.2^2 + 2.5^2$$
$$h^2 = 11.09$$

Calculate h

$$= \sqrt{h^2}$$
$$= 3.33$$

Calculate $\cos\phi$ using pythagoras

$$= \frac{d}{h}$$
$$= \frac{2.2}{3.33}$$
$$= 0.66$$
$$E_Q = \frac{1500}{11.09} \times 0.66$$
$$= 89.26 \text{ lux}$$



EXAMPLE 2 Two lamps are suspended 10m apart and at a height of 3.5 m above a surface (Figure 2). Each lamp emits 350cd. Calculate.
(a) the illuminance on the surface midway between the lamps,
(b) the illuminance on the surface immediately below each of the lamps.

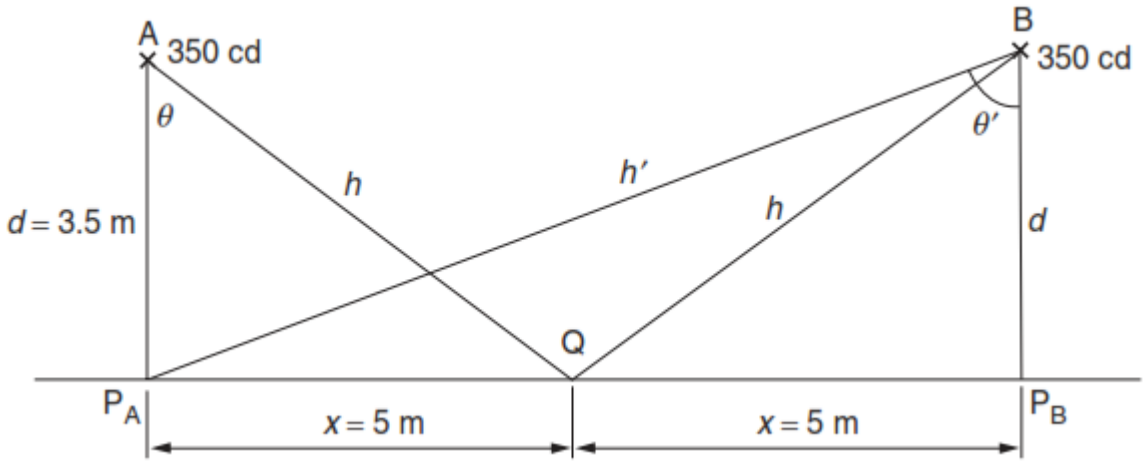


Fig.2

Solution :

(a) For one lamp, the illuminance at Q is

$$E_{\mathrm{Q}} = \frac{I}{h^2}\cos\theta$$

$$= \frac{350}{3.5^2 + 5^2} \times \frac{3.5}{\sqrt{(3.5^2 + 5^2)}}$$

$$= \frac{350}{12.25 + 25} \times \frac{3.5}{\sqrt{(12.25 + 25)}}$$

$$= \frac{350}{37.25} \times \frac{350}{\sqrt{37.25}}$$

$$= 5.388\,\mathrm{lx}$$

The illuminance from two lamps is double that due to one lamp, since the conditions for both lamps are identical. Thus total illuminance at Q = 2 × 5.388 = 11.8 lx

(b) At P_A below lamp A, the illuminance due to lamp A is

$$E_{\mathrm{P_A}} = \frac{I}{d^2}$$

$$= \frac{350}{3.5^2}$$

$$= 28.57\,\mathrm{lx}$$

In calculating the illuminance at PA due to lamp B, we have a new distance *h'* , a new distance *x'* , and a new angle *θ'* to consider.

$$x' = 2x$$

$$= 10$$

$$(h')^2 = 3.5^2 + 10^2$$

$$= 112.25$$

$$\therefore \quad (h') = 10.59$$

$$\cos\theta' = \frac{d}{h'} = \frac{3.5}{10.59} = 0.331$$

$\therefore$ illuminance at P_A due to lamp B is

$$E_{P_B} = \frac{350}{112.25} \times 0.331 = 1.013$$

$$\text{Total illuminance at } P_A = 28.57 + 1.013 = 29.61 \text{ lx}$$

and, as the conditions at PB are the same as those at PA , this will also be the illuminance below lamp B.

Problems

1. A lamp emitting 450 cd in all directions is suspended 3m above the floor. The illuminance on the floor immediately below the lamp is

(a) 150 lx **(b)** 1350 lx **(c)** 50 lx **(d)** 0.02 lx

2. If the lamp of question 7 is reduced in height by 0.5 m, the illuminance produced immediately below it is

(a) 72 lx **(b)** 36.7 lx **(c)** 129 lx **(d)** 180 lx

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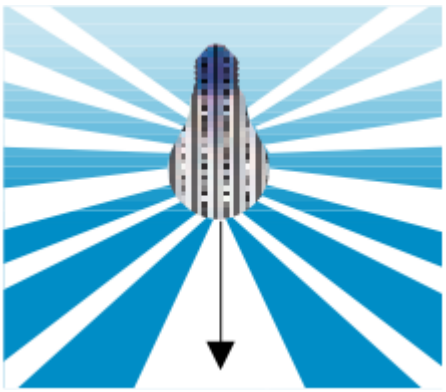

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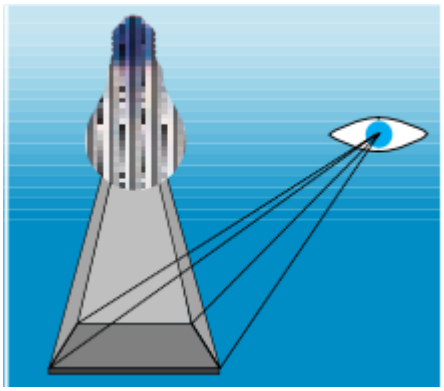

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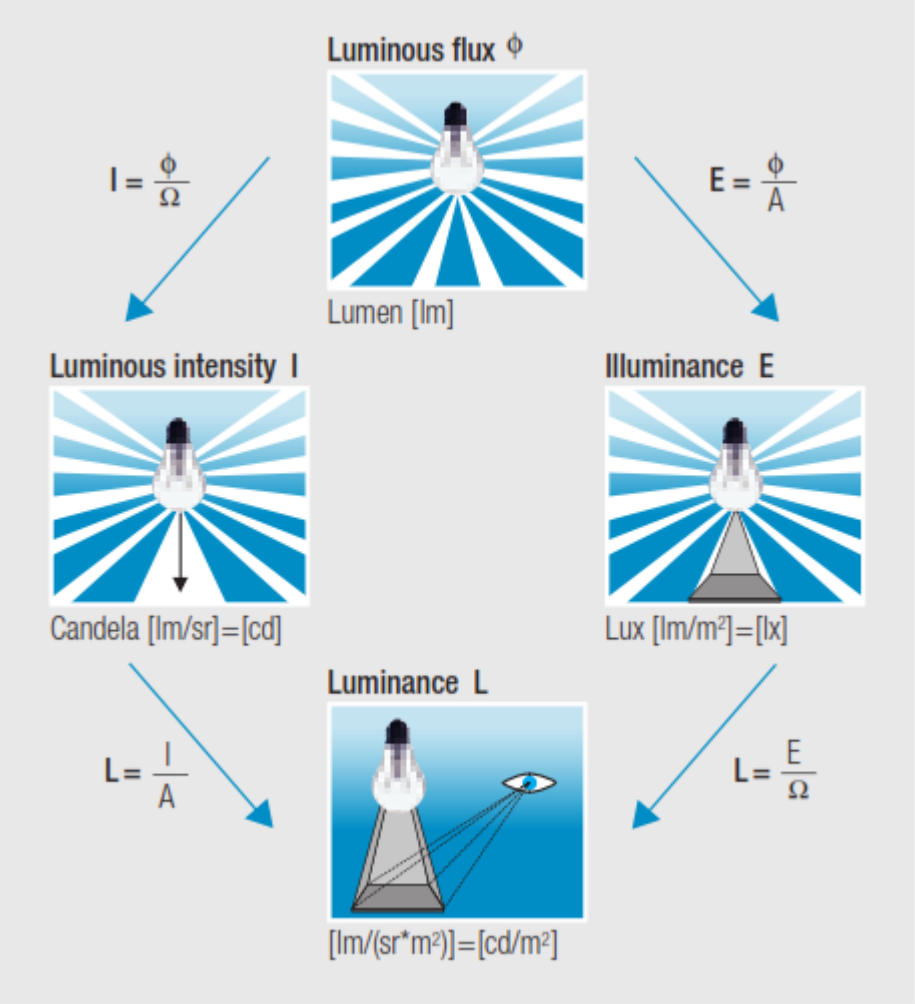

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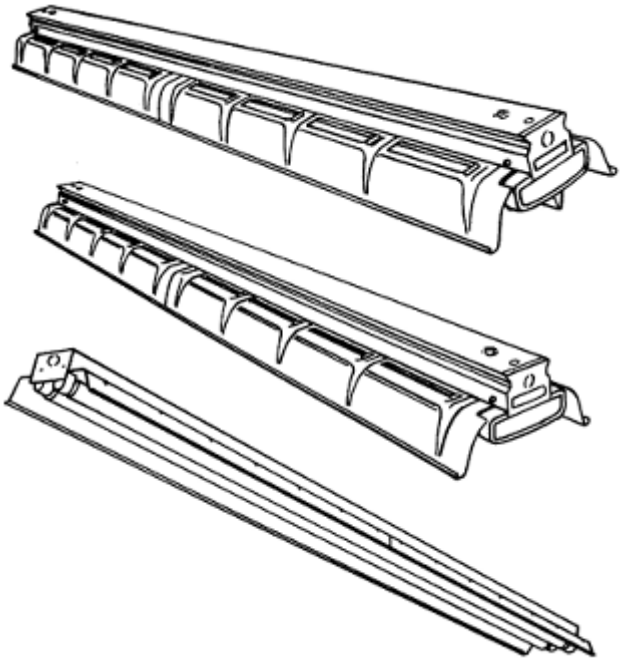

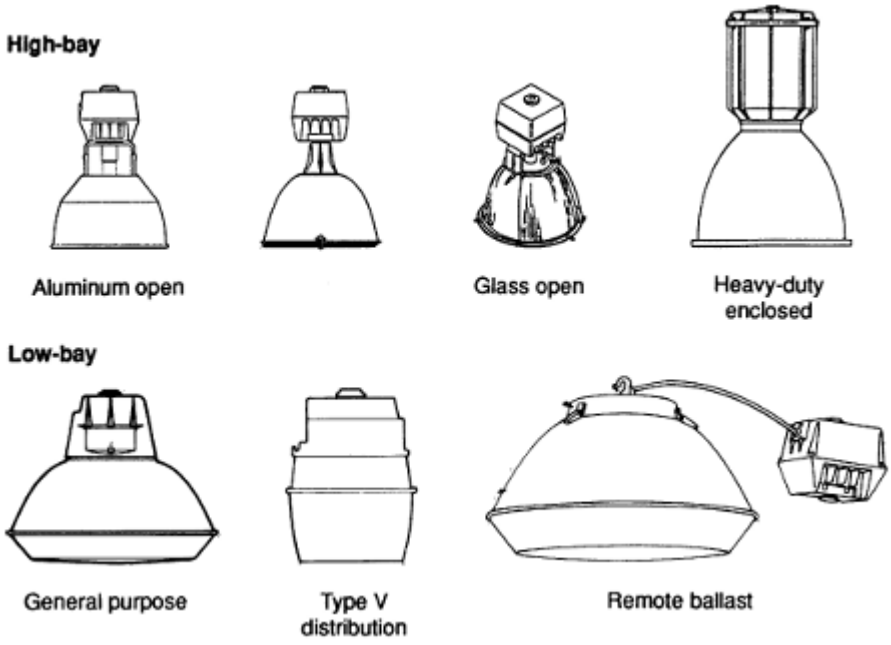
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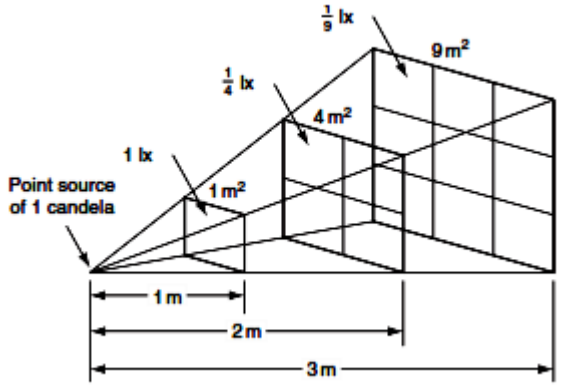
- Cosine law
- Lumen method (most common)
- Reflective index method

Inverse square law

Consider Rays of light falling upon a surface from some distance *d* will illuminate that surface with an illuminance of say 1 lx. If the distance *d* is doubled as shown in Fig. 2, the illuminance of 1 lx will fall over four square units of area. Thus the illumination of a surface follows the **inverse square law** .



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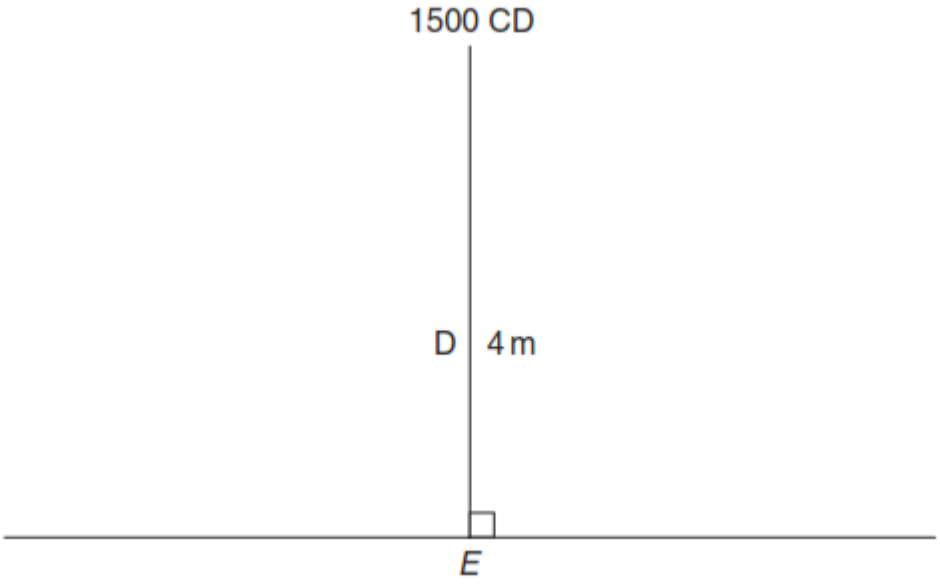

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$$E = \frac{1500}{(4+1)^2}$$
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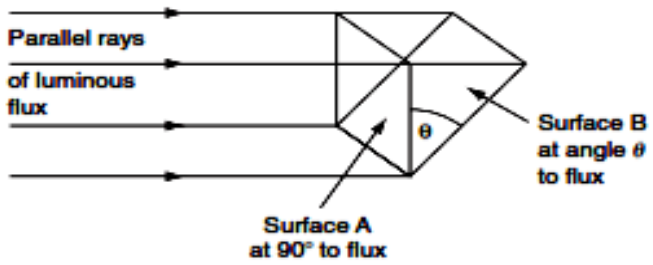
$$= 60 \text{ lux}$$

COSINE LAW

The illumination of surface A in Fig. 3 will follow the inverse square law described above. If this surface were removed, the same luminous fl ux would then fall on surface B. Since the parallel rays of light falling on the inclined surface B are spread over a larger surface area, the illuminance will be reduced by a factor θ, and therefore:



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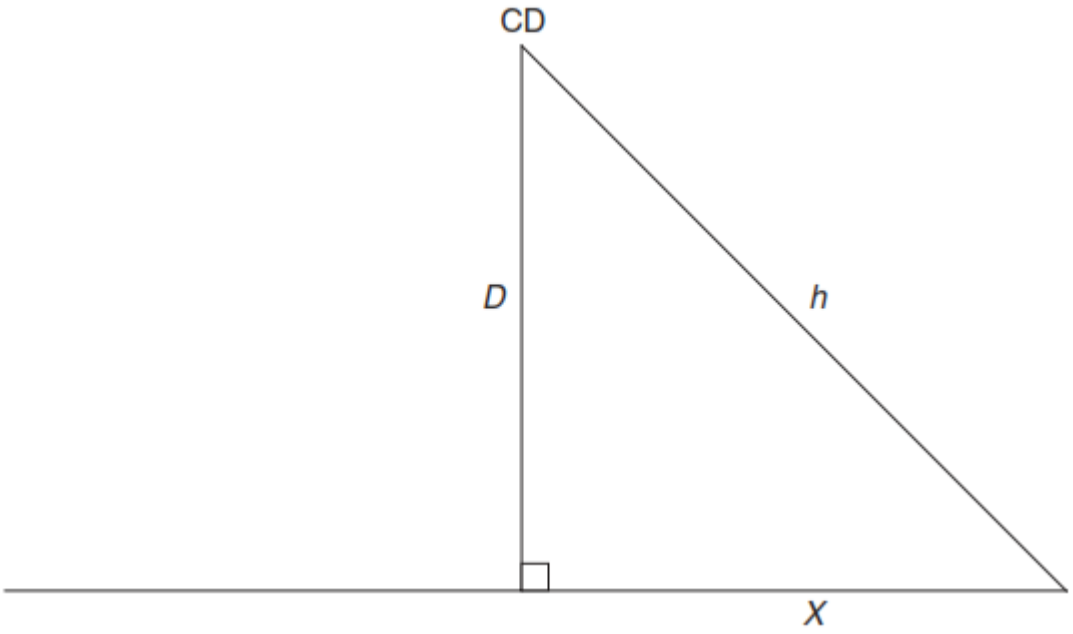

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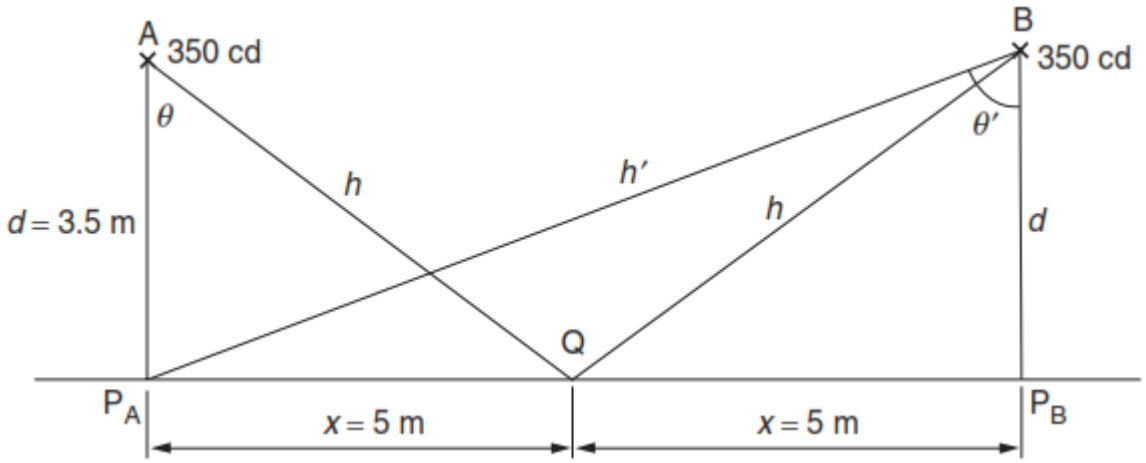

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$$\begin{aligned} E_{P_A} &= \frac{I}{d^2} \\ &= \frac{350}{3.5^2} \\ &= 28.57 \text{ lx} \end{aligned}$$

In calculating the illuminance at PA due to lamp B, we have a new distance *h'* , a new distance *x'* , and a new angle *θ'* to consider.

$$\begin{aligned} x' &= 2x \\ &= 10 \\ (h')^2 &= 3.5^2 + 10^2 \\ &= 112.25 \\ \therefore \quad (h') &= 10.59 \end{aligned}$$

$$\begin{aligned} \cos\theta' &= \frac{d}{h'} \\ &= \frac{3.5}{10.59} \\ &= 0.331 \end{aligned}$$

$\therefore$ illuminance at P_A due to lamp B is

$$E_{P_B} = \frac{350}{112.25} \times 0.331$$
$$= 1.013$$

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